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Reprint and Circular Series of the National Research Council

INDUSTRIAL BENEFITS OF RESEARCH

By Charles L. Reese
Chemical Director, E. I. du Pont de Nemours & Company
A. J. Wadhams
General Superintendent, International Nickel Company

Papers delivered before the Division of Engineering of the
National Research Council
February 4, 1921

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REPRINT AND CIRCULAR SERIES
OF THE
NATIONAL RESEARCH COUNCIL
NUMBER 18

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INTRODUCTION

Industries are dependent upon scientific research for their existence and progress. Stimulation of the industries to conduct research, and the education of their managers to appreciation of the necessity for research, are among the activities of the Division of Engineering of the National Research Council. To this end, at meetings of the Division distinguished speakers from the industries tell from their experiences, of the benefits derived from research, both the fundamental investigations in science and the experiments to solve industrial problems in the plant. Executives of corporations who might be interested to undertake research are invited as guests.

The principal speakers at the meeting of the Division of Engineering, February 4, 1921, were Dr. Charles L. Reese, Chemical Director of

* Papers delivered before the Division of Engineering of the National Research Council, February 4, 1921.

E. I. du Pont de Nemours Company, and Mr. A. J. Wadhams, General Superintendent of the International Nickel Company, Orford Works, Bayonne, N. J.

National Research Council is a cooperative organization of scientific men of America. Its members include, however, not only scientific and technical men, but also business men interested in science, engineering and industry. Established under the auspices of the National Academy of Sciences, with the cooperation of Engineering Foundation, it enjoys the support of most of the major scientific and technical societies, and governmental departments. Its membership is drawn from forty of these societies and the departments. The Council was organized in 1916 to coordinate the research facilities of the country for work on war problems. In 1918, by executive order of the President of the United States, it was reorganized as a permanent body, for the promotion of scientific research and of the application and dissemination of scientific knowledge for the benefit of the national strength and well-being.

The Council has thirteen divisions, arranged in two groups. One group comprises seven divisions of science and technology, representing physics, mathematics, and astronomy; chemistry and chemical technology; biology and agriculture; the medical sciences; psychology and anthropology; geology and geography; and engineering. The other group comprises six divisions of general relations, namely, foreign relations, government relations, states relations, educational relations, research extension and research information.

The Division of Engineering of the National Research Council, working in cooperation with Engineering Foundation, aims to carry out the general purpose of the Council in the field of engineering by stimulating research and coordinating the work of existing agencies. It seeks to minimize duplication, concentrate effort, and stimulate progress, but not in any case to dictate the procedure in its cooperative programs. It also encourages individual initiative.

The Division is made up largely of representatives appointed by engineering societies, and members at large selected because of special fitness. The membership includes fifteen past-presidents of engineering societies, high officials of governmental departments, and leaders in industry.

Division of Engineering
National Research Council
April 7, 1921.

BENEFITS OF RESEARCH TO CORPORATIONS

By Charles L. Reese

It is quite embarrassing for me, a chemist, to speak before an audience of engineers on the subject of the benefits derived by the du Pont Company from its research investigations and engineering developments, for, although I am familiar in many ways with the engineering developments, my experience has been mostly along the lines of chemical research and chemical engineering.

About twenty-five years ago, when I first went into industrial research work, there were very few industries in this country that recognized the importance of organized research and organized chemical control, and any work of this character done at all was handled by operative superintendents or managers of plants, through the ordinary works control laboratories and their operative mechanical engineers.

My first experience was with a company very large and strong for those days, that had a patented process before it for several years. The analyst, who had hundreds of routing analyses to make every day, was given the process to report upon. When I took over his notes, they were scattered throughout his regular note-book, and I could make no use of them whatsoever; but after two weeks of concentrated study I had worked out the process in detail and made a complete report in which I turned it down, much to the satisfaction of the officers of the company, who were especially relieved to be rid of the importunities of the inventor. This concern now has a very large, well-organized and successful research department.

In the study of industrial problems it is very difficult to separate true research from efficiency control, and from a chemical point of view, I might say chemical control of processes. As these two functions are so closely related and under one head in the organization of the du Pont Company, it will be necessary to include both in trying to present some of the benefits derived from the Research Department of the company.

When I first organized this department of the company's work in 1902, one of my first duties was to establish the research laboratory, and at the same time study the various manufacturing operations as they then existed. A thorough system of records was developed with a view to determining yields on raw materials, costs, etc., from a material point of view. Consequently, a very complete system of

records has been developed, so that at any time the du Pont Company can place its hands upon the records of efficiency of its operations during any period for the last twenty years. From a study of these records it soon developed what researches were necessary in order to improve going processes, and it was not long before great improvements were made in the old processes, and new ones developed for manufacturing old products.

In 1902 one of the serious difficulties met in the manufacture of nitro-glycerine was the long time required to separate the nitro-glycerine from the waste acids, especially with certain brands of glycerine, which were purchased under contract. This resulted in reducing production, and seriously increased the cost of manufacture. During the first year of the operation of the research laboratory the cause of this difficulty was discovered, and a remedy found which, capitalized, was worth at least a million dollars to the company as well as materially increasing the safety of the operation. The result of this one piece of research work was sufficient to carry the cost of the laboratory for a number of years.

During these early days most of the work of the research department was confined to subjects connected with the manufacture of high explosives and the raw materials entering into their manufacture. Soon after this a small experimental nitro-glycerine factory was constructed, and through a scientific study of this manufacture the yields have been brought up practically to theoretical standards, and the most economic ratios of raw materials have been used, resulting in enormous savings when applied to the great production of this material over a long period of years.

One of the greatest benefits from maintaining a research organization in any industry, and particularly in the chemical industry, is the fact that it will enable the manufacturer to keep ahead of the art, and thus be in a strong position to meet competition, both in quality and the cost of the product.

It is also of great advantage to the people and to the country at large, in that it ultimately reduces the selling prices of old products and gives them the benefit of new and useful ones, ofttimes adding to their comfort, happiness and safety, as well as to their self-defense. As an illustration of the above, I might mention the rapid development of new types of explosives, known as "Safety Explosives," for use in coal mines to prevent frequent explosions of gas and dust due to the use

of black powder. Although the Bureau of Mines has done much to standardize such explosives for the benefit of mankind, it may be interesting to you to know that the du Pont Company was the first to install the necessary equipment for testing such explosives in this country, and has developed certain explosives of this class which were on the market before the Bureau of Mines was established. We consequently have been a leader in this development, and have given the government the benefit of our advance knowledge.

Another benefit has been the development of certain explosives which would not freeze. One of the most serious dangers to the users of dynamite were the accidents brought about by carelessness in thawing frozen dynamite before use in the winter. In addition to doing away with this danger, the expense of storing in heated magazines was also eliminated.

Two types of low-freezing dynamites have been developed in this country. In one the freezing point of the nitro-glycerine is very much retarded by the use of nitro bodies dissolved in the nitro-glycerine, whereas in the other the freezing point of the nitro-glycerine is materially retarded by the polymerization of the glycerine. Although these two methods had been known in Europe for a number of years, they had never been put into practical operation, as far as I know, and it took several years, after the discovery of the methods, to make them practical in this country. I might say that many difficulties were met in the perfecting of this class of explosives.

The monetary value of discoveries of this nature cannot be calculated, nor can that of many of the other more important benefits derived from research work.

I might mention an interesting case of purely mechanical nature, the development of a machine for packing dynamite into the paper shells, which not only brought about a very large monetary saving, but also reduced to a minimum the danger connected with this operation. It does the work of thirty or forty operatives in plants I have seen in Europe, and although such machines have been in use for twenty odd years, I know of only one explosion having occurred, in which only two operatives were involved.

Another very important mechanical accomplishment, and one which was largely responsible for our ability to manufacture the enormous amount of smokeless powder for the United States and the Allies, is our Mechanical Cotton Dipper. In the old days about two pounds of

raw cotton were put in an earthenware pot, and nitrated by a man stirring nitric acid through it with a fork, and when this charge was completed, we had about three pounds of finished product, or nitro-cellulose. One pot could not be used more than twice a day, and to produce the amount of nitro-cellulose required it would have necessitated the actual daily use of about 500,000 pots, a place large enough to operate them, and thousands of men. It is obvious that this would have been impossible. By the use of the Mechanical Dipper, all these pots were discarded, and the amount of the charges considerably increased. As it required only about 150 men and very little space to operate these machines, we were able, with other improvements, to manufacture nearly a million and a half pounds of nitro-cellulose per day at one of our plants.

In the manufacture of nitro-cellulose many so-called fires occur, which more properly should be called "fume-offs." When these occur, it is necessary for the workmen to leave the building, and remain idle until it has been cleared of these fumes. Ordinary means of ventilation do not suffice, and therefore an aeroplane propeller was installed, which nearly instantly drives out these fumes, so that very little time is lost. I mention this because it has resulted in more regular operation of the plant, and also illustrates a valuable use which can be made of machinery designed for an entirely different purpose.

Several years ago one of the principal men at one of our research laboratories made the suggestion that a certain cheap raw material might be used in connection with glycerine for the manufacture of a liquid explosive. Although it took a number of years to perfect the invention and make it practical, by the partial substitution of this material, there resulted a net saving of practically one million dollars to the company in five years; the saving was realized principally in the last two or three of these five years. It is customary for the company to encourage its employees to make discoveries of this kind by awarding them bonus stock. It may be interesting to you to know that the research chemist who made this discovery received a bonus of common stock of the company that made him financially independent, and there have been many cases somewhat similar to this one.

Dr. Otto Witt, a celebrated chemical engineer, in an address before the International Congress of Applied Chemistry in London in 1909, spoke of the difficulties usually met in taking an industry or process from one country to another, using as an illustration the manufacture

of illuminating gas, which was taken from England, where it was developed, to France and Germany. My experience confirms this statement. In 1901, the contact process for the manufacture of sulphuric acid was brought here from Germany, but it took two years or more of scientific study and much sad experience, both on the part of the chemist and the engineer, to bring it to a satisfactory basis for the conditions in this country, although we had the benefit of the inventor's experience and guidance.

In 1908, after a visit to England and Germany, I became convinced that trinitrotoluol was the coming military high explosive. We secured all the available information from the other side, and made a thorough study of the process from a scientific point of view. After we had operated a small experimental plant and secured a contract from the government for the use of the explosive in submarine mines, we undertook its manufacture. This was the beginning of the manufacture of trinitrotoluol, or "T-N-T," in this country, and the wisdom of the venture was shown by the enormous tonnage of this explosive which, made in this country during the war, helped to win it. This, in connection with other work carried out in another laboratory organized for general research and particularly for the study of smokeless powder subjects, together with the well-organized research department, was a great factor in enabling the du Pont Company to meet the situation when the World War broke out. Much fundamental research work on smokeless powder was done at this laboratory, which seemed, at the time, to lead to no results, but I am going to call your attention to one or two facts which turned out to be of the greatest importance when the great war came on.

A new military rifle powder had been developed at the laboratory, but did not seem to meet the requirements of the American military rifle. Just before the war an Argentine Commission was seeking a powder which would be suitable for use in their rifle. When this powder was tried in our laboratory, it was found to suit admirably, and consequently we felt that our efforts in this direction had not been wasted. When it became necessary to furnish rifle powder for the Russian, British, and French rifles, this powder proved so successful that nearly ninety million pounds of it were manufactured for these countries. Although it is impossible to figure the monetary value of this development, as some other powder would undoubtedly have been used, if we take a fair royalty as a basis for figuring, it would represent a very large sum of money.

When we began to receive orders for large amounts of smokeless powder from the Allies, it became necessary to make for ourselves one of the most important ingredients for its manufacture—diphenylamine—which had previously been obtained from Europe. Chemists were immediately put to work, and a process developed which enabled us to supply all the diphenylamine necessary, and not a day's production of smokeless powder was delayed owing to the lack of this material. The first process was expensive, and consequently a better one was developed, which saved in the neighborhood of four hundred thousand dollars to the company.

Before the war all smokeless powder manufactured for the government was air dried in order to remove the excess solvent, and it required several months to finish the powder. A very exhaustive study had been made of a process for water drying used by the French. There was considerable doubt on the part of military experts in this country as to the advisability of water drying, but this piece of work proved the feasibility of the process without a doubt, so that when the great demand for smokeless powder came the information gained was immediately useful, and powder was made in a few days instead of in a few months.

Owing to the scarcity of toluol, two laboratories were put on the problem of finding a method of producing more of this material, and as a result two separate and distinct processes were developed and put into operation.

At the outbreak of the war it was absolutely impossible to secure lead burners to build our sulphuric acid plant at Hopewell, Virginia, and consequently the entire plant was built without the use of lead. This plant produced over one and a quarter million tons of sulphuric acid. This, I believe, is the first time a sulphuric acid plant has been built without the use of lead. As a result, a plant of 25,000 tons annual capacity was built in two months, with an additional unit, up to ten units, every seven days. With lead burning it would have been impossible to get this plant ready in any such time.

In the manufacture of over a billion pounds of smokeless powder, two hundred and sixteen million gallons of alcohol were used. Of this, eighty-six million gallons were consumed and one hundred and thirty million gallons were recovered by a process which had been developed before the war.

In this connection I should like to quote a statement made by Mr. Pierre S. du Pont, President of the du Pont Company, in his annual report for the year 1918:

> This enormous saving is largely attributable to the very efficient work of the Chemical and Mechanical Research Departments, including the laboratories of the Company, with the most intimate and earnest cooperation of the men in the factories themselves. The Chemical and Mechanical Research Departments numbered 212 men prior to the war, while at the end of the year 1918, 987 men were employed in this service. The economies effected by them and by those working in the factories have not been questions of dollars and cents alone, as conservation of materials saved was of prime importance to the world at large. Thus the reduction in consumption of alcohol was the equivalent to the saving of 10,400,000 bushels of corn. The total expenditure for experiment and research during the four years 1915–1918 amounts to $3,360,000.

As I have stated above, it would have been practically impossible for the company to have undertaken the manufacture of 1,466,761,291 pounds of military explosives had it not been for its chemical and engineering organizations. We manufactured not only smokeless powder, trinitrotoluol and picric acid, but also developed and manufactured tetryl and trinitroxylene, two explosives which had not been manufactured in this country before the war, as well as numerous explosive mixtures to help out the shortage in these materials.

An enormous amount of work was found necessary in order to develop satisfactory methods for loading that very successful high explosive developed in England, known as amatol, a mixture of trinitrotoluol and nitrate of ammonia. The trinitrotoluol acts as a cementing material for holding the grains of nitrate of ammonia together, and also acts as a sensitizing material to bring about the explosion of the nitrate of ammonia as well as the trinitrotoluol itself. It was found necessary to load this material while it was hot enough to maintain the liquid condition of the trinitrotoluol, for as soon as it cools, it solidifies, and the material forms a mass similar in structure to sandstone. This proved to be as satisfactory an explosive as trinitrotoluol itself, but great difficulty was experienced in properly loading into shells. Proper machinery had to be designed to meet the requirements, and after very large expenditure of time and money, this was successfully accomplished.

Tetryl, an explosive which was used exclusively in Germany before the war, is intended partially to replace fulminate of mercury in det-

onating or blasting caps. During the war it was used to a very large extent as a primer, in addition to fulminate of mercury, for high explosive shells, and there was a great demand for this material. In order to manufacture tetryl, the chemical name for which is tetra-nitro-dimethyl-aniline, it was necessary to manufacture dimethyl-aniline. It did not take long in the laboratory to develop a process for the manufacture of dimethyl-aniline, and this material has been manufactured ever since in sufficient quantities to supply all the tetryl needed for the war, and also the amount needed as an intermediate for dyes. This is one case that shows the very intimate relation between the dyes and munitions industries, about which so much has been said in the last two years in connection with legislation necessary to protect the infant dye industry.

A small experimental plant was quickly built for the manufacture of tetryl, and from this a large one was designed which was operated throughout the war without a single explosion. I mention this because tetryl is a very dangerous material to manufacture, and although we had secured some information in regard to its manufacture from Germany before the war, it was found that some of this information was positively misleading, and would have caused serious damage had we not discovered the error in the small experimental plant. The fact that this plant was operated without an accident is extremely interesting when we consider the fact that tetryl is a much more sensitive explosive than trinitrotoluol, or the so-called "T-N-T." There have been explosions in plants manufacturing this material, which up to the time of the war was considered a comparatively safe explosive.

Because of the success of our chemists in meeting the requirements for diphenylamine and toluene by synthetic processes, we were encouraged to believe that we had in our organization men who could master, through research, the great problem of producing dyes in this country, which were so much needed when the supply was cut off by the German monopoly. As we are manufacturers of explosives which require the same raw materials and similar processes to those used in the manufacture of dyes, we decided to branch out into the dye industry. This would not have been possible without the research organization which had been developed before the war, and grown so tremendously during the war. The fact that the du Pont Company is now producing a large line of satisfactory colors is proof of the service which a research organization can be to a manufacturing concern.

It might be interesting to state that the total expenditure of the du Pont Research Organization for the years 1912 to 1918 inclusive was $6,051,000, and the calculable saving, disregarding those benefits which cannot be figured in dollars and cents, though extremely important, amounts to $82,401,000. This large figure, of course, is increased very much by the enormous production during the war, and as a large part of this saving was in connection with the manufacture of smokeless powder, it enabled the company to reduce the price of powder materially during the war, in spite of the increased cost of raw materials and labor.

Since 1918 expenditures on research have increased. This is largely due to the great number of different industries in which the du Pont Company is interested—explosives, pyroxylin plastics, pyroxylin solutions, artificial leather, paint, pigment and varnish, and the nitrate industry—to say nothing of the highly technical and very complicated dye industry, which is still in its infancy. It is to the last named industry that the company is today devoting more than half of its research efforts. You will all recognize the fact that the dye industry could not be carried on, much less developed, without the most highly trained research organization. The progress which has been made up to the present is nothing short of marvelous, but there is still a great deal to be done to put this great American industry on a firm footing. Many millions have already been spent and many more will have to be spent on research to enable this American industry to meet German competition without protection, which is absolutely essential to its existence at present. It would take a miracle for our chemists in a few years to create the equivalent in details of what fifty years' experience has given the Germans, but even if they do, more will have to be done in the way of research to enable the industry to keep ahead of the art.

RESEARCH WORK FROM THE OPERATING MAN'S POINT OF VIEW

By A. J. Wadhams

We have just heard Dr. Reese's interesting comments on the great service rendered by the du Pont Company during the war. Before starting on the subject of "Research Work from the Operating Man's Point of View," I want to say something about the work done by The International Nickel Company during the war.

It is probably known to you all that nickel-steel is used very extensively in the manufacture of armor plate, gun forgings, bayonets, and other military equipment. Substantially all of the nickel for these steels required by the allied governments was supplied by The International Nickel Company. It meant a very busy time for us, supplying not only the nickel for ordnance steel but also large amounts for automobile construction, for shafting, and other parts, as well as the nickel used in copper-nickel alloys for bullet jackets, and for other purposes.

It was not until this pressure was removed that we took up seriously the question of research. During the times of good business, when there is an abnormal demand for production, questions which involve serious study do not, as a rule, receive much attention, as there is no urgent need for the results which intensive study might develop. This is not particularly any more true of The International Nickel Company than of other industries. When there is an over demand for tonnage which can be made, the energy and resources of the company are bent upon supplying that demand, with very little interest in development work.

It was, therefore, not until after the armistice that the question of developing and extending research work was brought to my attention. Since that time we have organized, and thoroughly equipped, a research department which has in hand a great number of projects.

For the purpose of discussion, I would divide research into two main sub-divisions:

First: That which comes from outside the company as the result of the use of the company's products, and under this heading, suggestions for new uses.

Second: Study of practice and resultant products in the shop. It is this second field of which I wish to speak.

We have all seen the research engineer attempting to gain information from the operating department. His usual experience is to find hurdles placed for him by the furnacemen and others, over which he must go, willy nilly. If he clears the hurdle, out he goes through the opposite door. If he fails, so much the better from the standpoint of the operating man, and still out he goes through the opposite door. This condition does not produce results and is usually the cause of building up between the technical man and the practical man solid barriers which are hard to remove later on.

In operating, the goal is production. That must be kept clearly in mind at all times by an operating man. The staff is organized with that purpose clearly in view and kept as the guiding star. This being the case, we must have double-fisted men as foremen and department superintendents in industry: men who can handle the tools themselves and know, by first-hand experience, how the job is done; men who have the driving force to put the plan through and get out the tonnage.

In order to have the research department men enter this field with any hope of success, they must realize fully that the operating man, through his experience, has a knowledge of the work which they have not. This must be an honest belief and not a mere say-so from the standpoint of expediency. The operating man is immediately conscious of the technique in the possession of the research man, which is somewhat beyond him. The chance of getting into the department without having the hurdles placed is gained by showing an honest appreciation of the value of the operating man's knowledge. The accomplishment of this depends largely upon personalities. There is no simple formula by which it can be done.

The advance must be made by the technical man; the operating man will, in my opinion, seldom if ever make the advance. The easiest avenue of approach is, I believe, one of information, offered by the technical man to the operating man, not in a spirit of superiority, but in a spirit of exchange for real values received from the operating man.

You remember the poster during the war, showing a man producing the machine gun, and above him, in a vision, the man using the machine gun. The impetus given to the man by this sort of picture was a great stimulus to production in a great many industries. Particularly is this true of multiple machine jobs; the individuals have little or no knowledge of the product before it comes to them, nor what their effort has added to its value.

The idea is to interest the operating man by showing a picture of the processes through which the material has passed before it comes to his department and how, through his effort, it is enabled to be passed on to the next step. Show him how the process works. Get him interested in the reactions which actually occur in his own work; in other words, let in the light; take off the roof and knock down one side of the building of the man's mind, so that he sees the thing in a way in which he has never seen it before.

This is the opportunity the research man has in dealing with the operating man. If he can use it, there is scarcely a limit to what may be achieved. Under these conditions there will be no hurdles for the technical man while he is in the operating department, and his field of vision, in turn, will be so enlarged that his usefulness will be greatly enhanced.

It is usually a question of educating the man up to his job and letting in the light.

There is another group which you might say is in need of being educated down to this problem; that is, the boards of directors. It is often difficult to capitalize results of research. . Improvements in the shop practice often have far reaching results yet cannot be evaluated in dollars and cents. In a major improvement it is sometimes difficult to determine fairly what part of it should be credited to research; other factors may have played an important part. More interest on the part of boards of directors in the visions of the research department is necessary to stimulate the work.

In my opinion close cooperation between the research department and the operating departments opens up possibilities for intelligent advancement which will be productive of great results.

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